JPPIPA 9(12) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Improving Mental Models and Mental Modelling Ability in Electrical Circuit Context: A Problem-Solving Approach with House Installation Model

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Received: September 6, 2023
Revised: November 7, 2023
Accepted: December 20, 2023
Published: December 31, 2023

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DOI: 10.29303/jppipa.v9i12.5225

Abstract: The purpose of this study was to improve students' Mental Models and Mental Modelling Ability in the context of electrical circuits by using the House Installation Model as a laboratory learning instrument. The problem-solving-based laboratory learning model was applied in this research. The research method utilized a descriptive qualitative research design with a pretest-posttest design. The research results showed that 75% of students experienced Mental Models improvement in the context of electrical circuits, with 15% reaching level 2 and 60% reaching level 3. The improvement in Mental Modelling Ability was also significant, with 80% of students experiencing improvement, 21.7% reaching a moderate level, and 58.7% reaching a high level of Mental Modelling Ability. These results suggest that problem-solving-based practice learning models can effectively improve students' Mental Models and Mental Modelling Ability in the context of electrical circuits.

Keywords: Electrical circuit; Mental model (MM); Mental modelling ability (MMA); Practice learning; Problem solving.

Introduction

The motivation behind this research stems from the observed deficiencies in the understanding of electrical networks among students enrolled in the Basic Concept of School Physics 1 Course (Anwar et al., 2023). Previous research has highlighted a concerning trend wherein a significant portion of students struggled to accurately describe electrical networks in a household setting. Supriyatman et al. (2017) conducted an analysis of students' mental models in the context of electrical circuits, revealing that only 17.2% reached level 1, 71.4% at level 2, and a mere 11.4% at level 3. This indicates that while students were familiar with series and parallel concepts, they encountered difficulties applying them to problem-solving scenarios (Azizah et al., 2022; Melawati et al., 2022; Halim et al., 2021). Moreover, it was noted that the supporting concepts for electrical circuits were introduced in the first semester during the Basic of Physics 2 Course (Hidayat et al., 2023).

The findings from this analysis underscored a crucial issue: a majority of prospective Physics teacher students, particularly those in the Basic Concept of School Physics 1 Course, struggled to solve problems accurately (Dewi et al., 2023; Oxana et al., 2023; Hidayati et al., 2020). This difficulty became more pronounced when facing problems requiring additional knowledge beyond what was taught in the course (Aulia et al, 2022; Fajria et al., 2018). Despite having learned the necessary concepts in earlier courses, students exhibited a partial understanding, making it challenging for them to integrate and apply these concepts coherently (Tanel & Erol, 2008). Their shortcomings were evident in their analytical, evaluative, constructive, and interpretative abilities (Supriyatman, 2016; Tanel & Erol, 2008), indicating a deficiency in both Mental Model (MM) and

How to Cite:
Kade, A., Supriyatman, Pasaribu, M., Untara, K. A. adi., & Supriyadi. (2023). Improving Mental Models and Mental Modelling Ability in Electrical Circuit Context: A Problem-Solving Approach with House Installation Model. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11422–11428. https://doi.org/10.29303/jppipa.v9i12.5225

Mental Modeling Ability (MMA) (Batlolona, et al., 2020; Kurnaz & Eksi, 2015).

Scientists, as problem solvers, play a crucial role in advancing knowledge and addressing real-world challenges. Korsunsky (2004) emphasized the essence of Physics learning as the development of students' problem-solving capabilities. However, the existing learning approaches have fallen short in effectively equipping students with these skills (Nadrah, 2023). Consequently, there is a pressing need to enhance learning strategies that foster the development and application of mental models in problem-solving processes (Hamdiyati et al., 2022).

In light of the identified challenges, the research question emerged: Can an experimental problem-solving-based learning model effectively address and improve students' mental models and mental modeling abilities? Therefore, the objective of this research is to investigate whether an experimental problem-solving-based learning model, utilizing house installation media in the context of electrical series materials, can rectify students' mental models and enhance their mental modeling abilities, specifically focusing on prospective Physics Teacher students.

Method

The type of this research is a descriptive qualitative research. This research used a pretest-posttest design with research stages covered preparation, treatment, and report. The course process was conducted by using laboratory learning of problem solving experimental model based on media of house installation. The laboratory learning implementation was guided by using LKM consisted of 3 modules such as series-parallel combination, application 1 of switch and lamp combination, and application 2 of switch and lamp combination.

The course participants were 41 students and only 20 students were willing to become respondents of this research. These 20 students were batch 2016 who programmed Basic Concept of School Physics 2 Course at even semester in 2018 consisted of 6 males and 14 females. All respondents had completed Basic Physics 1 and Basic Physics 2 Courses. The learning activities were conducted in Physics laboratory of Faculty of Teacher Training and Educational Science Tadulako University for 4 meetings.

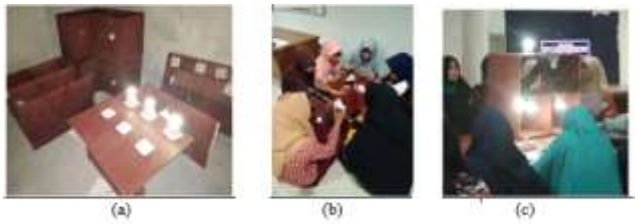

Figure 1. Learning Process. a) Practice Equipments, b) Practice Activities, and c) Presentation Activity.

Problem solving test. This test was used to determine the mental model and category/model of problem solving owned by the students. This test had the students write all thought in working on problem solving in a piece of paper until their thought pattern will be captured and described in finding the answer from the problem being faced. The interview guideline used to complete the data of the test result on problem solving was clarification. The interview was conducted on some subjects which represented each category of mental model or problem solving.

Model Mental data were obtained from analysis result of test answer on problem solving obtained at answer sheet of each student. The analysis was conducted by using MM rubric. MMA data were obtained from the analysis result of test answer on problem solving obtained at the answer sheet of each student. The analysis was conducted by using MMA Rubric that referred to categorization conducted (Supriyatman, 2016) the result of his categorization (Wang, 2007). MMA categorization can be seen in table 1, where X is the score obtained from problem solver.

Table 1. Categorization of mental modeling ability

MMA Categorization	Score
High-MMA (H-MMA)	$7 < x \geq 10$
Moderate-MMA (M-MMA)	$3 < x \geq 7$
Low-MMA (L-MMA	$0 < x \leq 3$

Qualitative data analysis was conducted considering the profile of mental model and MMA which is abstract and needs deep analysis through test and also interview. This analysis was conducted in three stages, such as: Data reduction is the process of selecting, centralizing attention on simplification and choosing things obtained from test delivery, and interview. In analyzing Mental Model (MM), attention centralization was conducted based on the criteria which appeared in the process of solving the problem. While MMA analysis, based on the scores in the criteria which appear in the result of problem solving.

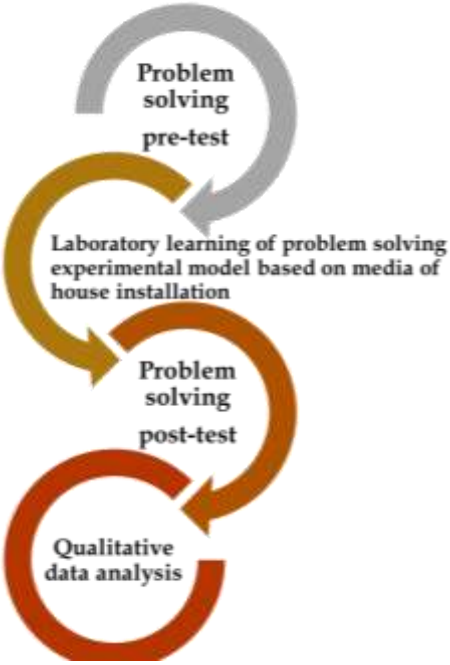

Figure 2. Research flow laboratory learning of problem solving experimental model based on media of house installation

Figure 2 shows the flow of the research. Data presentation is done by collecting information obtained from the results of data reduction in the form of tables, to provide the possibility of drawing conclusions and taking action. The data that has been presented is then interpreted and evaluated to make decisions. Decision making regarding the mental level model and the MMA category of students based on the results of data presentation.

Result and Discussion

Data of MM and MMA were collected during the learning process following the phases of problem solving learning model experimental based. The data then were analyzed in two categories, such as mental model (MM) and Mental Modeling Ability (MMA) improvement.

The Profile of Students' Mental Model Improvement

MM data were obtained through problem solving test consisted of 3 number of essay questions. This test was conducted in the beginning and at the end of the learning process. To know the process of MM improvement on each respondent by using MM rubric that had been made. In short, students' MM profiles are showed in Table 2. Table 2 shows that students with mental model level 1 is easier to be improved by using problem solving learning model practice based compared to students who are at mental model category level 2.

Table 2. Distribution of MM student improvement in each context

Context							Level MM
		Pre-Test	Post Test				Amount
			NC	Level 1	Level 2	Level 3	
1	NC	0	0	0	0	0	0
	Level 1	R1, R2, R3, R4, R6, R10, R12, R13, R14, R15, R17, R18, R19, R20	0	R19	R2, R13, R18	R1, R3, R4, R6, R10, R12, R14, R15, R17, R20	14
	Level 2	R9, R11, R16	0	0	R9	R11, R16	3
	Level 3	R5, R7, R8	0	0	0	R5, R7, R8	3
	Amount	0		1	4	15	20
2	NC	0	0	0	0	0	0
	Level 1	R1, R9, R12, R13, R15	0	0	R13, R15	R1, R9, R12	5
	Level 2	R2, R3, R4, R5, R6, R7, R8, R10, R11, R14, R16, R17, R18, R19, R20	0	0	R3, R8, R14, R16, R17, R18, R20	R2, R4, R5, R6, R7, R10, R11, R19	15
	Level 3	0	0	0	0	0	0
	Amount	20	0	0	9	11	20
3	NC	0	0	0	0	0	0
	Level 1	R1, R6, R7, R9, R12, R13, R15, R16, R18	0	R9	R1, R12, R18	R6, R7, R13, R15, R16	9
	Level 2	R2, R3, R4, R5, R8, R10, R11, R14, R17, R19, R20	0	R17	R2, R3, R8, R14, R20	R4, R5, R10, R11, R19	11
	Level 3	0	0	0	0	0	0
	Amount	0	0	2	8	10	20
		Average improvement			3 (15%)	12 (60%)	15(75%)

The Profile of Mental Modeling Ability (MMA) Improvement

MMA dtaa were obtained from the test of problem solving conducted in the beginning and at the end of learning process. To know the process of MMA improvement in each respondent, then analysis was conducted towards the result of the initial test and the final test of each respondent by using MMA rubric. In short, the analysis result of students' MMA is showed in Table 3.

Table 3 shows that the initial test for context number 1, students' MMA is at NC category with total 1 person (5%), L-MMA category in the amount of (60%), M-MMA category in the amount of 5 people (25%), and H-MMA category in the amount of 2 people (10%). In context number 2, students' MMA is at NC category with total 1 person (5%), L-MMA category in the amount of 12 people (60%), and M-MMA category in the amount of 7 people (35%). While in context number 3, students' MMA is at NC category with total 2 people (10%), L-MMA category in the amount of 9 people (45%), M-MMA category in the amount of 8 people (40%), and H-MMA category in the amount of 1 person (5%).

Table 3. Distribution of student MMA improvement in each context

Context	Category MMA						
	Pre-Test		Post Test				Amount
			NC	L-MMA	M-MMA	H-MMA	
1	NC	R17	0	0	0	R17	1
	L-MMA	R1, R2, R3, R4, R6, R10, R12, R13, R14, R15, R18, R20	0	0	R13, R14, R18	R1, R2, R3, R4, R6, R10, R12, R15, R20	12
	M-MMA	R7, R8, R9, R16, R19	0	R19	R9	R7, R8, R16	5
	H-MMA	R5, R11	0	0	0	R5, R11	2
	Amount	20	0	1	4	15	20
2	NC	R9	0	0	R9	0	1
	L-MMA	R1, R2, R3, R4, R5, R6, R10, R14, R15, R16, R17, R18	0	0	R1, R16, R17, R18	R2, R3, R4, R5, R6, R10, R14, R15,	12
	M-MMA	R7, R8, R11, R12, R13, R19, R20	0	0	R8, R19, R20	R7, R11, R12, R13	7
	H-MMA	0	0	0	0	0	0
	Amount	0	0	0	8	12	20
3	NC	R6, R9	0	R9	0	R6	2
	L-MMA	R1, R2, R3, R5, R12, R13, R15, R16, R18	0	R1, R12,	R2, R3, R13, R15, R18	R5, R16	9
	M-MMA	R4, R7, R8, R10, R11, R17, R19, R20	0	0	R8, R17 R19, R20	R4, R7, R10, R11,	8
	H-MMA	R14	0	0	0	R14	1
	Amount	20	0	3	9	8	20
Average increase of MMA				1	4,3 (21,7%)	11,7 (58,3%)	16 (80,0%)

The analysis result of final test obtained for context number 1, students' MMA is at NC category with total 0 person (0%), L-MMA category in the amount of 1 person (5%), M-MMA category in the amount of 4 people (20%), and H-MMA category in the amount of 15 people (75%). In context number 2, students' MMA are at NC category in the amount of 0 person (0%), L-MMA category in the amount of 0 person (0%), M-MMA category in the amount of 8 people (40%), and H-MMA category in the amount of 12 people (60%). While in the context number 3, students' MMA are at NC category with total 0 person (0%), L-MMA category in the amount of 3 people (15%), M-MMA category in the amount of 9 people (45%), and H-MMA category in the amount of 8 people (40%).

Table 3 also shows that after following problem solving learning model practice based, the students experienced MMA improvement. In the context number 1, students' MMA improvement is at NC category (1 person) to H-MMA category. Students from L-MMA

category are in the amount of 12 people (60%) experience improvement to be M-MMA category in the amount of 3 people (15%) and becomes H-MMA category in the amount of 9 people (45%). The students from M-MMA category are in the amount of 5 people (25%) experience improvement to be H-MMA in the amount of 3 people (15%), 1 person (5%) experience decrease to be L-MMA category, and 1 person (5%) stays at M-MMA category. While the students with H-MMA category in the amount of 2 people (10%) stay in this category.

In the context number 2, students' MMA improvement from NC category (1 person) to M-MMA category. Students from L-MMA category in the amount of 12 people (60%) experience improvement to be M-MMA category in the amount of 4 people (20%) and become H-MMA category in the amount of 8 people (40%). The students from M-MMA category in the amount of 7 people (35%) experience improvement to be H-MMA in the amount of 4 people (20%) and 3 people (15%) stay in M-MMA category. While in context number 3, students' MMA improvement from NC category (2 people) become M-MMA category and H-MMA category. The students from L-MMA category in the amount of 9 people (45%) experience improvement to be M-MMA category in the amount of 5 people (25%), become H-MMA category in the amount of 2 people (10%), and 2 people (10%) stay in L-MMA category. The students from M-MMA category in the amount of 8 people (40%) experience improvement to be H-MMA category in the amount of 4 people (20%), and 4 people (20%) stay in M-MMA category. While students with H-MMA category in the amount of 1 person (5%) stays in this category.

The learning strategy used in this research was Problem Solving Learning Model Experimental Based that is developed by Supriyatman, et al (2018). The syntax of this model in the learning implementation are as follows: Phase 1, The students are guided to review the prior knowledge owned related to the concept that will be used in problem solving. This phase is the initial stage of forming students' mental model (Dewi et al, 2023; Bhalwankar & Treur, 2021; Barry & Lazarte, 1998). Phase 2, the students were individually trained to make mental model based on the context of the problem given as the riddle of the previous step (Haili, 2021; Rayanto, 2020). The initial construction of mental model process is built in the form of mind mapping in their brain (min) as a process of finding the concepts, knowledge, and suitable experience to the problem that they are working on (Sari et al., 2019; Bucciarelli, 2007; Sunyono & Ibrahim, 2015). Phase 3, the students are trained in group to reveal the relationship betweed concept and the prior knowledge related to the riddle (the problem) faced (Batlolona et al., 2020). In this phase, each student is expected to reveal the mental model kept in their own brain (mind mapping) related to the problem faced and then discuss it. Until the suitable model is obtained to solve the problem and plan the experiment (Aulia et al., 2022; Sutarno et al., 2017; Vosniadou, 2009). Phase 4, the students are trained to prove the truth of the model that has been agreed in group through experimental activities. This activity indirectly trained the students to conduct MMA high indicator. Phase 5, the students are trained to express the process of problem solving in front of the class in group. The students are challenged to transform the model that has been build in group into other explanations such as table, graph, and pictures that are also the indicators of high MMA. Phase 6, is the reinforcement and follow up of the learning process filled with the explanation of mind mapping related to the problem context displayed in constructing mental model, and giving isomorphic test related to the problem which function to train and develop the ability of mental model construction and prospective teachers' MMA, and giving the preliminary assignment (pre-explanation) for the next meeting.

MM repair and MMA improvement as explained above are in line with the research (Supriyatman, 2016). This condition also shows that experimental learning problem solving based can improve the ability of prospective Physics teacher students in solving the problem (Kawuwung & Mamahit, 2023; Hendriana et al., 2018). This ability is marked by the presence of students' strategy in analyzing the problem, working on the solution, until monitoring the process of solving the problem. These strategies are the parts of MMA category assessment aspect.

Conclusion

The practice media of house installation model and experiment learning model problem solving based can fix mental model and improve mental modeling ability of the students of prospective Physics teacher at Electrical Series Concept. This ability is marked with the change of students' strategy in analyzing the problem, working on the solution, until monitoring the process of problem solving. The recommendation based the results of this research is that it is necessary to develop experiment learning problem solving based in improving the ability of Prospective Physics Teacher students in other concepts. This learning beside can access the conception and ability of problem solving, also can be used to evaluate process of course learning.

Acknowledgments

The writer would like to thank the Chancellor of Tadulako University for the acceptance of this research proposal and for the willingness of funding this research.

Author Contributions
Writing-original draft preparation, conceptualization, methodology, conclusion, A; formal analysis, writing—review and editing, S, M; validation, supervision, and resources, K, S.

Funding
This research was funded by Chancellor of Tadulako University in accordance with Decree Number 3352/UN28/KP/2018.

Conflicts of Interest
The authors declare no conflict of interest.

References

Anwar, P. I., Rifai, H., Ferdinal, F., Zulaikah, S. ., Husna, H., Lisa, T. D. P., & Fitriani, D. (2023). Study Of Physics Concepts In Cave Exploration Activities To Develop Physics Edupark Digital Book For Senior High School Students. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4431–4442. https://doi.org/10.29303/jppipa.v9i6.3408

Aulia, I. M., Hikmawati, and Susilawati. (2022). Pengaruh model pembelajaran berbasis masalah terhadap kemampuan pemecahan masalah fisika peserta didik pada materi usaha dan energi. *Jurnal Pendidikan Fisika dan Teknologi*, 8, 52–57. https://doi.org/10.29303/jpft.v8ispecialissue.3558

Azizah, U., and Nasrudin, H. (2022). Problem solving thinking skills: effectiveness of problem-solving model in teaching chemistry college students. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1462–1469. https://doi.org/10.29303/jppipa.v8i3.1700

Barry, S., and Lazarte, A. A. (1998). Evidence For Mental Models: How Do Prior Knowledge, Syntactic Complexity, And Reading Topic Affect Inference Generation In A Recall Task For Nonnative Readers Of Spanish? *The Modern Language Journal*, 82(2), 176–193. https://doi.org/10.2307/329207

Batlolona, J. R., Diantoro, M., Wartono, and Leasa, M. (2020). Students' Mental Models Of Solid Elasticity: Mixed Method Study. *Journal of Turkish Science Education*, 17(2), 200–210. https://doi.org/10.36681/tused.2020.21

Batlolona, J. R., Singerin, S., and Diantoro, M. (2020). Influence Of Problem Based Learning Model On Student Mental Models. *Jurnal Pendidikan Fisika Indonesia,* 16(1), 14-23. https://doi.org/10.15294/jpfi.v16i1.14253

Bhalwankar, R. & Treur, J. (2021). Modelling The Development Of Internal Mental Models By An Adaptive Network Model. *Procedia Computer Science*, 190, 90–10. https://doi.org/10.1016/j.procs.2021.06.011

Bucciarelli, M. (2007). How The Construction Of Mental Models Improves Learning. *Mind & Society*, 6(1), 67–89. https://doi.org/10.1007/s11299-006-0026-y

Dewi, F. H., Samsudin, A., Chandra, D. T., Aminudin, A. H., Kunaedi, J., Astuti, I. R. W., Umar, F. A., and Mufida, S. N. (2023). How Is Students' Mental Model In The Post-Pandemic Era? Work And Energy Concept Analysis Using The Wright Map. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1260–1268. https://doi.org/10.29303/jppipa.v9i3.2773

Dewi, W. S., Siregar, R., Putra, A., and Hidayati, H. (2023). The effect of problem-based learning model on students' physics problem solving ability: a meta-analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2103–2109. https://doi.org/10.29303/jppipa.v9i4.3291

Fajria, F., Rahmatan, H., & Halim, A. (2018). Dampak model pembelajaran problem solving terhadap motivasi dan hasil belajar peserta didik di smp. *Jurnal Pendidikan Sains Indonesia*, 5, 87–94. https://doi.org/10.24815/jpsi.v5i2.9822

Haili, H. (2021). The portrait of students' mental modelling ability on the concept of kinetic theory of gases in science literacy. *Advances in Social Science, Education and Humanities Research*, 633, 117-124. Retrieved from https://www.atlantis-press.com/article/125968422.pdf

Halim, A., Susanna, Evendi, Yusrizal, Musdar, and Irwandi, I. (2021). The impact of the problem-based instruction model on the students' problem solving ability. *AIP Conference Proceedings*, 2330(1). https://doi.org/10.1063/5.0043124

Hamdiyati, Y., Soesilawaty, S. A., and Habibah, S. N. (2022). Analysis Of High School Student's Mental Model On Virus: Representation Of Students' Conceptions. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 1790–1797. https://doi.org/10.29303/jppipa.v8i4.1879

Hendriana, H., Johanto, T., and Sumarmo, U. (2018). The role of problem-based learning to improve students' mathematical problem-solving ability and self confidence. *Journal on Mathematics Education*, 9(2), 291–300. https://doi.org/10.22342/jme.9.2.5394.291-300

Hidayat, H., Hidayat, O. S., and Widiasih, W. (2023). Development Of Google Sites-Based Learning Resources To Improve Mastery Of Concepts And Process Skills In Electrical Circuit Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4624–4631. https://doi.org/10.29303/jppipa.v9i6.3612

Hidayati, R. M., and Wagiran, W. (2020). Implementation Of Problem-Based Learning To

Improve Problem-Solving Skills In Vocational High School. *Jurnal Pendidikan Vokasi*, 10(2), 177–187. https://doi.org/10.21831/jpv.v10i2.31210

Kawuwung, F. R., & Mamahit, J. A. (2023). Analysis Of Classroom Action Research Studies: The Effectiveness Of Inquiry Learning Models On Biology Education Undergraduate Students Problem Solving Ability. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6136–6146. https://doi.org/10.29303/jppipa.v9i8.4258

Korsunsky, B. (2004). Ready, set, go! *The Physics Teacher*, 42(8), 493–497. https://doi.org/10.1119/1.1814326

Kurnaz, A. M., and Eksi, C. (2015). An analysis of high school students' mental models of solid friction in physics. *Educational Sciences: Theory and Practice*, 15(3), 787–795. https://doi.org/10.12738/estp.2015.3.2526

Melawati, O., Evendi, E., Halim, A. ., Yusrizal, Y., & Elisa, E. (2022). The influence of the use of student worksheet problem-based to increase problem solving skills and learning outcomes. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 346–355. https://doi.org/10.29303/jppipa.v8i1.1205

Nadrah, N. (2023). Linear Motion Materials On Authentic Learning In Collaborative Problem-Solving Model: Validity Aspects. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10067–10076. https://doi.org/10.29303/jppipa.v9i11.5587

Oxana, P. J, Hidayati, Afrizon, R., & Hidayat, R. (2023). The practicality of applying physics learning games with scientific literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 4938–4947. https://doi.org/10.29303/jppipa.v9i7.3883

Rayanto, Y. H. (2020). Learner's Pseudo Mental Model On Performing English Speaking Task Ability. *ELT Worldwide*, 7(2), 150-156. Retrieved from https://ojs.unm.ac.id/ELT/article/download/14544/pdf

Sari, I. M., Malik, A., Saepuzaman, D., Rusdiana, D., and Ramalis, T. R. (2019). Pre-Service Physics Teachers' Mental Models Of Heat Conduction: A Case Study Of The Process-Analogy Of Heat Conduction. *Journal of Physics: Conference Series*, 1157(3). https://doi.org/10.1088/1742-6596/1157/3/032073

Sunyono, Y, L., & Ibrahim, M. (2015). Supporting Students In Learning With Multiple Representation To Improve Student Mental Models On Atomic Structure Concepts. *Science Education International*, 26(2), 104-125. Retrieved from https://files.eric.ed.gov/fulltext/EJ1064043.pdf

Supriyatman, S., Suhandi, A., Rusdiana, D., Samsudin, A., Wibowo, F. C., and Mansyur, J. (2018). Design of Experimental Problem Solving-Based Learning Program to Improve Mental Model and to Enhance Mental-Modeling Ability. *Jurnal Pendidikan Fisika Indonesia*, 14(2), 73–82. https://doi.org/10.15294/jpfi.v14i2.6279

Supriyatman. (2016). *Pengembangan Program Perkuliahan Kelistrikan dan Kemagnetan Berbasis Pemecahan Masalah Untuk Memperbaiki Model Mental dan Meningkatkan Mental Modeling Ability Mahasiswa Calon Guru Fisika*. Bandung: UPI Bandung.

Sutarno, S., Setiawan, A., Suhandi, A., Kaniawati, I., & Putri, D. (2017). Keterampilan Pemecahan Masalah Mahasiswa Dalam Pembelajaran Bandul Fisis Menggunakan Model Problem Solving Virtual Laboratory. *Jurnal Pendidikan Fisika dan Teknologi*, 3(2), 164-172. http://dx.doi.org/10.29303/jpft.v3i2.396

Tanel, Z., & Erol, M. (2008). Students' Difficulties in Understanding the Concepts of Magnetic Field Strength, Magnetic Flux Density and Magnetization. Lat. Am. *Journal Physics Education,* 2(3), 184–191. Retrieved from https://dialnet.unirioja.es/descarga/articulo/2734609.pdf

Vosniadou, S. (2009). *International Handbook of Research on Conceptual Change*. New York: Routledge.

Wang, C. Y. (2007). *The Role of Mental-Modeling Ability, Content Knowledge, and Mental Models in General Chemistry Students' Understanding about Molecular Polarity.* Missouri: University of Missouri.